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(71) Applicant: JOHNSON & JOHNSON VISION CARE, INC. [US/US]; 7500 Centurion Boulevard, Suite 100, Jacksonville, FL 32256 (US).

(72) Inventor: MENEZES, Edgar, V.; 6558 Hidden Woods Drive, Roanoke, VA 24018 (US).

(74) Agent: GIANNESCHI, Lois, A.; Johnson & Johnson, One Johnson & Johnson Plaza, New Brunswick, NJ 08933 (US).

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(54) Title: PROGRESSIVE ADDITION LENSES WITH MODIFIED CHANNEL POWER PROFILES

(57) Abstract: The present invention provides multifocal ophthalmic lenses. In particular, the invention provides lenses in which channel power progression modification is achieved without a significant increase in unwanted astigmatism.

# PROGRESSIVE ADDITION LENSES WITH MODIFIED CHANNEL POWER PROFILES

## Field of the Invention

The present invention relates to multifocal ophthalmic lenses. In particular, the invention provides lenses in which channel power progression modification is achieved without a significant increase in unwanted astigmatism.

## Background of the Invention

The use of ophthalmic lenses for the correction of ametropia is well known. For example, multifocal lenses, such as progressive addition lenses ("PALs"), are used for the treatment of presbyopia. Typically, a PAL provides distance, intermediate, and near vision zones in a gradual, continuous progression of increasing dioptric power. PALs are appealing to the wearer because the lenses are free of the visible ledges between the zones of differing optical power that are found in other types of multifocal lenses, such as bifocals and trifocals.

As the wearer's eyes move from the distance, through the intermediate, and into the near vision zones of a PAL, the wearer's eyes converge bringing the pupils closer together. Ideally, the design of a PAL would be such that the power progression from the distance zone, through the intermediate and to the near zone matches the wearer's requirements as the eye scans the lens. However, in the design of conventional PAL's, a trade-off is made between the power progression distribution and the level of unwanted astigmatism of the lens.

Unwanted astigmatism is astigmatism introduced or caused by one or more of the lens surfaces resulting in image blurring, distorting, and shifting for the lens wearer. In order to reduce unwanted astigmatism, the power progression is distributed over a greater length in some designs. Due to this lengthened distribution, the power distribution may not meet the wearer's requirements and the wearer may have to alter their natural viewing posture, or head and eye position, in order to use the intermediate and near vision zones of the lens. Additionally, a lens

with a lengthened channel cannot fit into the smaller spectacle frames currently preferred by lens wearers. In those lens designs in which the power progression distribution is over a shorter length, the level of unwanted astigmatism is increased reducing the useable area of the lens. Thus, a need exists for a PAL that provides a modified channel power progression, but that does not significantly increase the lens' unwanted astigmatism.

## Brief Description of the Drawings

FIG. 1 is a diagrammatic representation of the lens power profile of the lens of Example 1.

FIG. 2 is a diagrammatic representation of the surface and lens power profiles of a lens of the invention.

FIG. 3 is a diagrammatic representation of the surface and lens power profiles of a lens of the invention.

FIG. 4 is a diagrammatic representation of the surface and lens power profiles of a lens of the invention.

FIG. 5 is a diagrammatic representation of the surface and lens power profile of a lens of the invention.

FIG. 6 is a diagrammatic representation of the surface and lens power profile of a lens of the invention.

FIG. 7 is a diagrammatic representation of the surface and lens power profile of a lens of the invention.

FIG. 8 is a diagrammatic representation of the surface and lens power profile of a lens of the invention.

FIG. 9 is a diagrammatic representation of the surface and lens power profile of a lens of the invention.

## Description of the Invention and its Preferred Embodiments

The present invention provides progressive addition lenses, as well as methods for their design and production, in which the power distribution between

the distance and near vision zones is modified. This modified distribution permits the requirements of the lens wearer's eye path to be met. Further, the modified distribution may be used to permit the lens to be used in spectacle frames of any dimensions. The modified channel power distribution of the lenses of the invention is obtained without reducing the useable lens surface by introducing a significant amount of additional unwanted astigmatism.

In one embodiment, the invention provides a lens comprising, consisting essentially of, and consisting of: a.) at least one first surface that is a progressive addition or regressive surface, the at least one first surface having a first channel with a first channel length and a channel power profile and; b.) at least one modifying surface having a power profile, wherein the channel power profile of the lens is the vector sum of the first surface's channel power profile and modifying surface's power profile and the lens channel power profile, channel length, or both is modified relative to the first surface's channel power profile and channel length. By " lens" is meant any ophthalmic lens including, without limitation, spectacle lenses, contact lenses, intraocular lenses and the like. Preferably, the lens of the invention is a spectacle lens.

By "progressive addition surface" is meant a continuous, aspheric surface having distance and near viewing or vision zones, and a zone of increasing dioptric power connecting the distance and near zones. By "regressive surface" is meant a continuous, aspheric surface having zones for distance and near viewing or vision, and a zone of decreasing dioptric power connecting the distance and near zones. By "channel" is meant the corridor of vision that is free of unwanted astigmatism of about 0.75 diopters or greater when the wearer's eye is scanning through the

intermediate vision zone to the near vision zone and back. By "channel power profile" is meant the power distribution along the channel length. By "channel length" is meant the distance from the lens' fitting point to a point along the channel at which the dioptric add power is about 85 percent of the dioptric add power of the surface. By "fitting point" is meant the point on a lens aligned with the wearer's

pupil in its distance viewing position when the wearer is looking straight ahead. By "power profile" is meant the power distribution along a modifying surface. By "modified" is meant one or both of a change in the channel power profile or a change in the channel length.

It is one discovery of the invention that a channel power profile of one or more progressive addition or regressive surface may be modified by combining the surface with one or more modifying surfaces. A modifying surface, for purposes of this invention, is a continuous, aspherical surface having a power profile, the power profile with one or more power maxima along its length, one or more power minima along its length, or a combination thereof. The modifying surface may be a rotationally symmetric surface without a channel, but preferably is a progressive or regressive surface. The modifying surface power profile is designed so that, when the modifying surface is combined with one or more of a progressive addition or regressive surface, the channel power profile, the channel length, or a combination thereof of the progressive addition surface or regressive surface is altered. The alteration may be of the power distribution along the channel, while the original channel length is maintained. Alternatively, the channel power profile may change and the channel length may be lengthened or shortened. The modifying surface power profile, preferably, is continuous and exhibits no abrupt power changes to avoid introduction of unwanted astigmatism or image jumps into the lens.

One ordinarily skilled in the art that any of a variety of positions of the modifying surface power profile in relation to the progressive addition or regressive surfaces' channel power profile may be used in order to achieve the desired

modification of the channel power profile. For example, the top and bottom of the modifying surface's power profile and progressive addition or regressive surface channels may be aligned. As an alternative example, in the case in which the modifying surface has a minimum in the power profile and the surface is used in combination with a progressive surface, preferably the start of the modifying surface power profile will be aligned with the top portion of the progressive addition or regressive surface channel. This alignment acts to subtract power from the progressive

surface power profile and shorten the channel length of the resulting lens. As yet another alternative, a modifying surface is combined with a progressive surface, the modifying surface with a maximum in its power profile preferably is situated so that the end of the modifying surface power profile will be aligned with the with the lower portion of the progressive addition surface's channel so that it adds power to, or increases, the power in the channel's lower portion. This alignment serves to result in a lens that reaches full near vision power using a shorter length. For the previously described alternatives, the alignment will be reversed in case in which the modifying surface is used in combination with a regressive surface. Finally, in the case in which the modifying surface power profile has both a maximum and a minimum, the start of the modifying surface's power profile may be aligned with the progressive or regressive surface's channel's top portion. This alignment may be used to increase or decrease the power over substantially all of the channel length or to form a plateau of a specified power within the channel.

The modifying surface may or may not provide additional dioptric add power to the lens. By "dioptric add power" is meant the amount of dioptric power difference between the distance and near vision zones. Preferably, the modifying surface provides less than about 3.50 diopters, more preferably less than about 1.00 diopters, most preferably less than about 0.50 diopters. By limiting the dioptric add power contribution of the modifying surface, the introduction of unwanted astigmatism into the lens is minimized.

The progressive addition, regressive, and modifying surfaces useful in the invention may be designed and optimized using any known method including, without limitation, the use of commercially available design software. The progressive addition, regressive, and modifying surfaces may be on a convex surface, a concave surface, a surface intermediate a convex and concave surface, or any combination thereof.

One ordinarily skilled in the art will recognize that one or more progressive addition or regressive surfaces may be used in combination with a modifying surface.

Additionally, the features resulting from the physical combination of a modifying and progressive addition or regressive surface may be incorporated into a single lens surface. More than one modifying surface also may be used with one or more progressive addition and regressive surfaces. For example, a modifying surface with a power maximum in combination with a modifying surface having a power minimum may be used in combination with one or more of a progressive surface, regressive surface, or a combination thereof.

The channel power profiles and power profiles for each surface used in the lenses of the invention may be selected from a variety of profiles including, without limitation, linear, spline, trigonometric, and the like. In the case in which one or more progressive addition or regressive surfaces is used, the channel power profile for each such surface may be the same or different.

The dioptric add power of each surface used in the invention is selected so that, when the surfaces are combined, the add power of the lens is substantially equal to that needed to correct the lens wearer's near vision acuity. The dioptric add power of each progressive addition surface individually may be about 0.25 diopters to about 3.50 diopters, preferably about 0.50 diopters to about 3.25 diopters, more preferably about 1.00 diopters to about 3.00 diopters. For each regressive surface,

the dioptric add power may be about -0.25 diopters to about -3.50 diopters, preferably about -0.50 diopters to about -3.25 diopters, more preferably about –0.75 diopters to about -3.00 diopters.

The refractive power range over the power profile for each modifying surface individually may be about –2.00 to about + 2.00 diopters, preferably about –1.00 to about + 1.00 diopters, more preferably about –0.50 to about +0.50 diopters. The progressive addition, regressive, and modifying surfaces each additionally may contain spherical power, cylinder power and axis, or combinations thereof.

The lenses of the invention may be fabricated by any convenient means and constructed of any known material suitable for production of ophthalmic lenses. Suitable materials include, without limitation, polycarbonate, allyl diglycol, polymethacrylate, and the like, and combinations thereof. Such materials are either commercially available or methods for their production are known. Further, the lenses may be produced by any conventional fabrication technique including, without limitation, grinding, whole lens casting, molding, thermoforming, laminating, surface casting, and the like, and combinations thereof. Casting may be carried out by any means including, without limitation, as disclosed in United States Patent Nos. 5,147,585, 5,178,800, 5,219,497, 5,316,702, 5,385,672, 5,480,600, 5,512,371, 5,531,940, 5,702,819, and 5,793,465 incorporated herein in their entireties by reference.

The lenses of the invention may be manufactured to stock or in a custom manufacturing system. If custom manufacturing is used, the modifying surface to be used for a particular prescription may be selected from an inventory of modifying surfaces to produce the desired channel power profile most suitable to a particular lens wearer.

The invention will be clarified further by the following, non-limiting examples.

## Examples

### Example 1

A conventional progressive lens is provided with a convex progressive addition surface and a concave spherical surface. The convex surface distance vision zone curvature is 6.00 diopters and the near vision zone curvature is 8.00 diopters. The channel length is 18 mm. The concave surface curvature is 6.00 diopters. The lens distance power is 0.00 diopters and the dioptric add power is 2.00 diopters. The power profile for the lens is depicted in FIG. 1.

### Example 2

A lens of the invention is provided with a convex progressive addition surface with a distance vision zone curvature of 6.00 diopters, a near vision zone curvature of 7.80 diopters and a channel length of 18 mm. The convex surface power profile is depicted in FIG. 2. The lens concave modifying surface's power profile, also depicted in FIG. 2, starts at 0.00 diopters, decreases to –0.31 diopters, and then increases to 0.20 diopters. The beginning of the convex and concave surface power profiles are aligned. The resulting, combined power profile, the lens power profile, is shown in FIG. 2. The lens channel length is 13 mm and the lens dioptric add power is 2.00 diopters.

## Example 3

A lens of the invention is provided with a convex progressive addition surface with a distance zone curvature of 6.00 diopters, a near zone curvature of 8.00 diopters and a channel length of 18 mm. The convex surface power profile is depicted in FIG. 3. The lens concave modifying surface's power profile, also depicted in FIG. 3, starts at 0.00 diopters, decreases to –0.31 diopters, and then increases to 0.00 diopters. The convex and concave surface power profiles are aligned so that the modifying surface power decrease is aligned with the top portion of the convex surface's channel. The resulting, combined power profile, the lens power profile, is shown in FIG. 3. The lens channel length is 14 mm. The lens dioptric add power is 2.00 diopters and is contributed entirely by the convex progressive surface.

## Example 4

A lens of the invention is provided with a convex progressive addition surface made of a material with a 1.65 refractive index. The convex surface has a distance zone curvature of 6.00 diopters, a near zone curvature of 7.34 diopters and a channel length of 18 mm. The convex surface power profile is depicted in FIG. 4. The concave surface is made of a material with a 1.50 refractive index and is also a progressive surface. The distance curvature of the concave surface is 6.00 diopters, the near curvature is 5.33 diopters, the dioptric add power is 0.67 diopters and the channel length of 18 mm. The concave power profile is shown in FIG. 4. The modifying surface is intermediate the convex and concave surfaces and the power profile, shown

in FIG. 4, begins at 0 diopters, decreases to – 0.27 diopters and then increases to 0 diopters.

The minimum curvature of the modifying surface ("MC") is 7.17 and is derived as follows:

$$MC = DC - MP \times \frac{n_1 - 1.00}{n_1 - n_2}$$

wherein $n_1$ and $n_2$ are the refractive indices of the convex and concave surface materials and DC is the distance curvature, 6.00 diopters. The resulting lens, the power profile of which is shown in FIG. 4, has a distance power of 0.00 diopters, and add power of 2.00 diopters, and a channel length of 14 mm.

Example 5

A lens of the invention is provided with a convex progressive surface with a distance zone curvature of 6.00 diopters, a near zone curvature of 8.00 diopters and a channel length of 18 mm. The convex surface power profile is depicted in FIG. 5. The lens concave modifying surface's power profile, also depicted in FIG. 5, starts at 0.00 diopters, increases to 0.20 diopters, and then decreases to 0.00 diopters. The concave surface power increase is aligned with the lower portion of the convex surface power profile. The resulting, combined power profile, the lens power profile, is shown in FIG. 5. The lens channel length is 16 mm and the lens dioptric add power is 2.00 diopters.

Example 6

A lens of the invention is provided with a convex progressive addition surface with a distance zone curvature of 6.00 diopters, a near zone curvature of 0 diopters and a channel length of 18 mm. The convex surface power profile is depicted in FIG. 6. The lens concave modifying surface's power profile, also depicted in FIG. 6, starts at 0.00 diopters, decreases to -0.20 diopters, increases to 0.20 diopters, and finally decreases to 0.00 diopters. The beginning of the convex and concave surface power

profiles are aligned. The resulting, combined power profile, the lens power profile, is shown in FIG. 6. The lens channel length is 12 mm and the lens dioptric add power is 2.00 diopters.

Example 7

A lens of the invention is provided with a convex progressive addition surface with a distance zone curvature of 6.00 diopters, a near zone curvature of 8.00 diopters and a channel length of 19 mm. The convex surface power profile is depicted in FIG. 7. The lens concave modifying surface's power profile, also depicted in FIG. 7, starts at 0.00 diopters, increases to 0.34 diopters, decreases to

-0.15 diopters, and finally increases to 0.00 diopters. The beginning of the convex and concave surface power profiles are aligned. The resulting, combined power profile, the lens power profile, is shown in FIG. 7. The lens channel length is maintained at 19 mm, the channel power profile of the lens having an intermediate plateau at 1.00 diopters over a length of 4 mm, and the lens dioptric add power is 2.00 diopters.

Example 8

A lens of the invention is provided with a convex progressive addition surface with a distance zone curvature of 6.00 diopters, a near zone curvature of 8.00 diopters and a channel length of 19 mm. The convex surface power profile is depicted in FIG. 8. The lens concave modifying surface's power profile, also depicted in FIG. 8, starts at 0.00 diopters, increases to 0.19 diopters, decreases to -0.20 diopters, and finally increases to 0.00 diopters. The beginning of the convex and concave surface power profiles are aligned. The resulting, combined power profile, the lens power profile, is shown in FIG. 8. The lens channel length is increased to 21 mm and the lens dioptric add power is 2.00 diopters.

Example 9

A lens of the invention is provided with a convex progressive addition surface with a distance zone curvature of 6.00 diopters, a near zone curvature of 8.00 diopters

and a channel length of 19 mm. The convex surface power profile is depicted in FIG. 9. The lens concave modifying surface's power profile, also depicted in FIG. 9, starts at 0.00 diopters, increases to 0.26 diopters, and finally decreases to 0.00 diopters. The beginning of the convex and concave surface power profiles are aligned. The resulting, combined power profile, the lens power profile, is shown in FIG. 9. The lens channel length is reduced to 18 mm, the channel power

profile of the lens is increased over the entire channel length, and the lens dioptric add power is 2.00 diopters.

What is claimed is:

1. A lens comprising: a.) at least one first surface that is a progressive addition or regressive surface, the at least one surface having a first channel with a first channel length and a channel power profile and; b.) at least one modifying surface having a power profile, wherein the channel power profile of the lens is the vector sum of the first surface's channel power profile and the modifying surface's power profile and the lens channel power profile, channel length, or both is modified relative to the first surface's channel power profile and channel length.

2. The lens of claim 1, wherein the lens is a spectacle lens.

3. The lens of claim 1, wherein the at least one surface is a progressive addition surface.

4. The lens of claim 1, wherein the at least one surface is a regressive surface.

5. The lens of claim 1, wherein the modification is a change in the channel power profile.

6. The lens of claim 5, wherein the channel power is increased in the lower portion of the channel.

7. The lens of claim 5, wherein the power is increased over substantially the entire channel length.

8. The lens of claim 5, wherein a power plateau is formed within the channel.

9. The lens of claim 5, wherein the modification further comprises a change in the channel length.

10. The lens of claim 1, wherein the modification is a change in the channel length.

11. The lens of claim 10, wherein the channel length is shortened.

12. The lens of claim 10, wherein the channel length is lengthened.

13. A lens comprising: a.) at least one first progressive addition surface, the first surface having a first channel with a first channel length and a channel power profile and; b.) at least one modifying surface having a power profile, wherein the channel power profile of the lens is the vector sum of the first surface's channel power profile and modifying surface's power profile and the lens channel power profile, channel length, or both is modified relative to the first surface's channel power profile and channel length.

14. A method for providing a lens with a modified channel power profile, the method comprising the steps of :

a.) providing at least one first surface that is a progressive addition or regressive surface, the at least one surface having a first channel with a first channel length and a channel power profile and;

b.) providing at least one modifying surface having a power profile wherein the channel power profile of the lens is the vector sum of the first surface's channel power profile and the modifying surface's power profile and the lens channel power profile, channel length, or both is modified relative to the first surface's channel power profile and channel length.

15. The method of claim 14, wherein the lens is a spectacle lens.

16. The method of claim 14, wherein the at least one surface is a progressive addition surface.

17. The method of claim 14, wherein the at least one surface is a regressive surface.

18. The method of claim 14, wherein the modification is a change in the channel power profile.

19. The method of claim 18, wherein modification further comprises a change in the channel length.

20. The method of claim 14, wherein the modification is a change in the channel length.

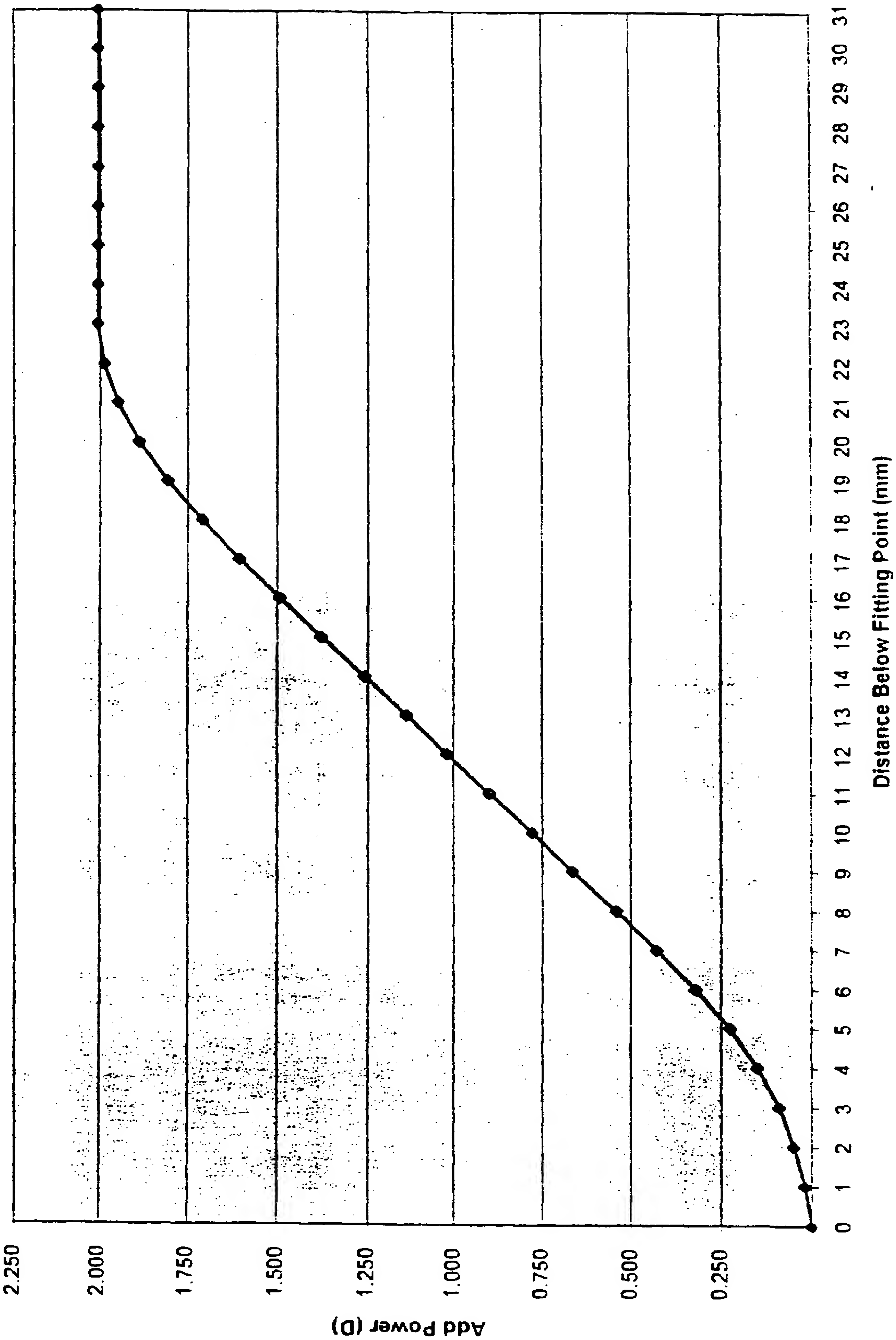



Fig. 1: Lens Channel Profile

Fig 2: Example 2 Channel Profiles

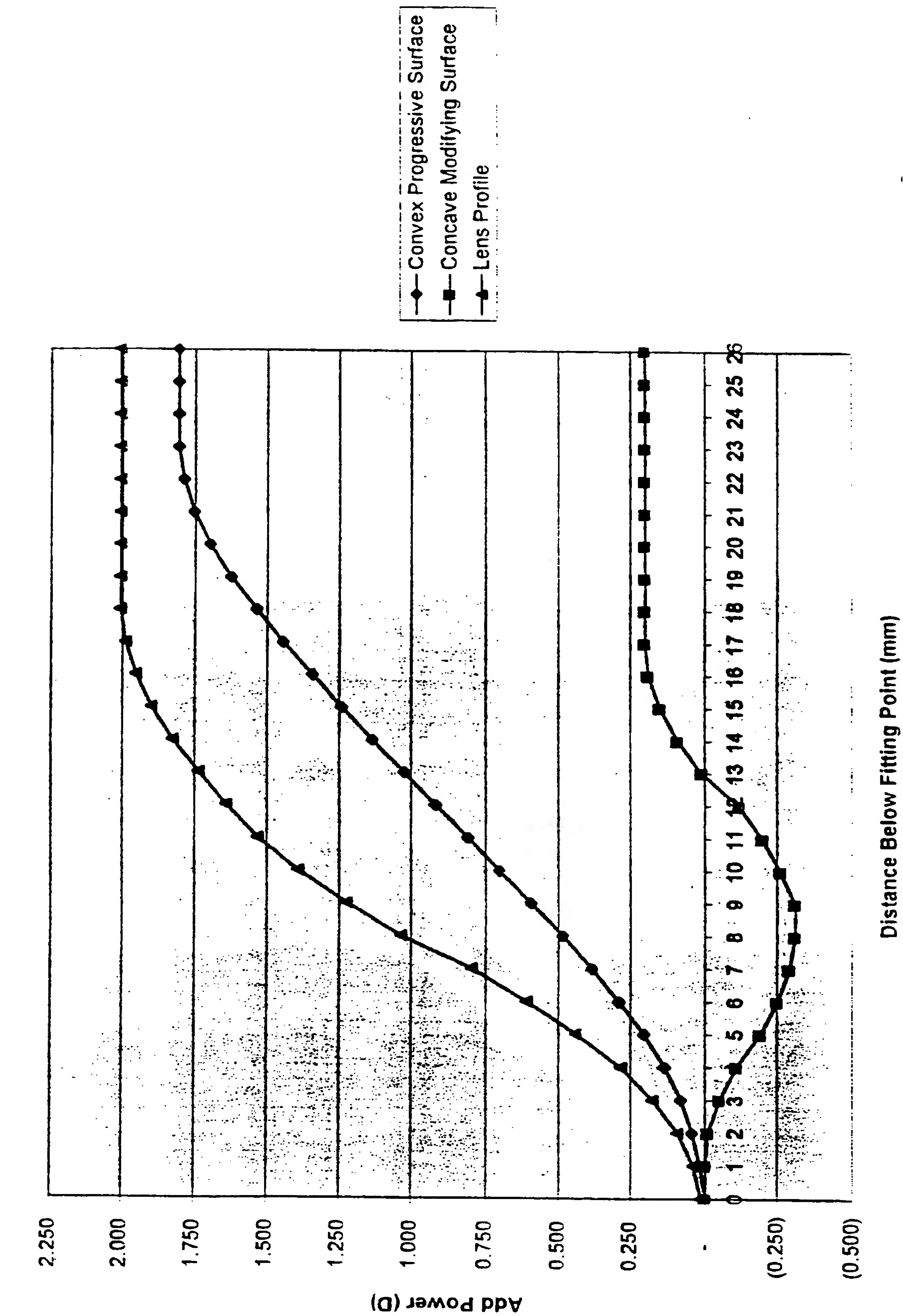
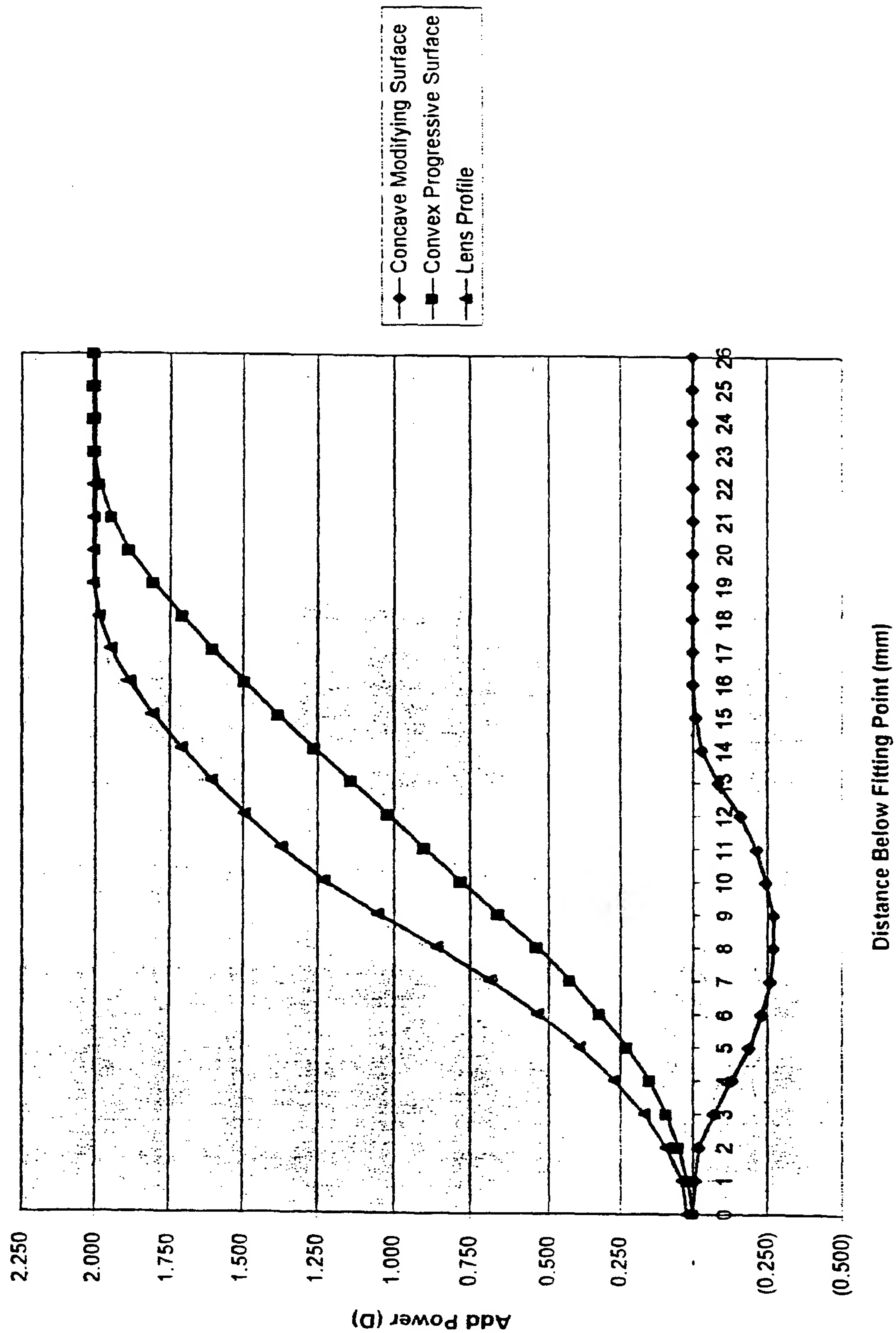


Fig 3: Example 3 Channel Profiles



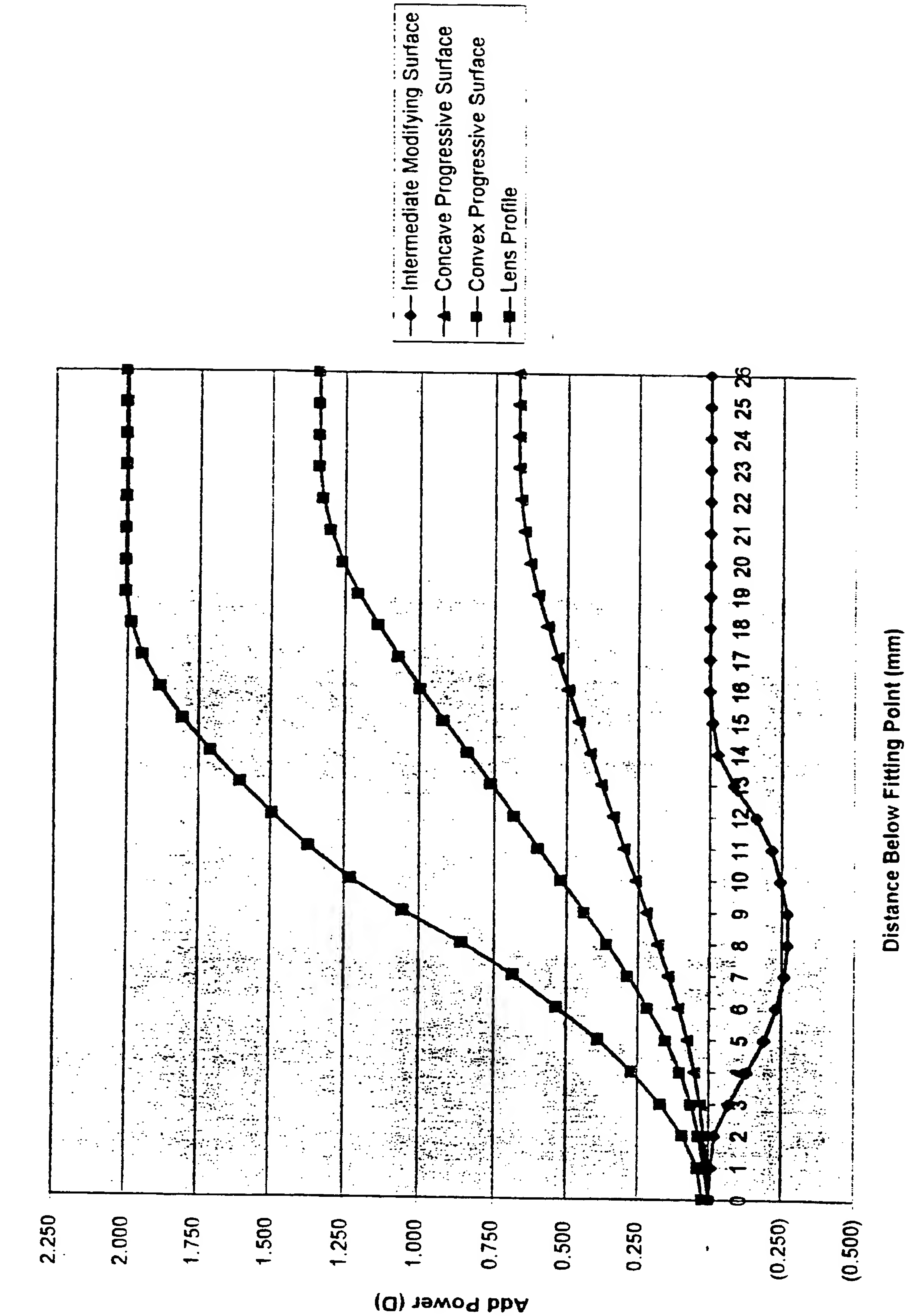



Fig 4: Example 4 Channel Profiles

Fig 5: Example 5 Channel Profiles

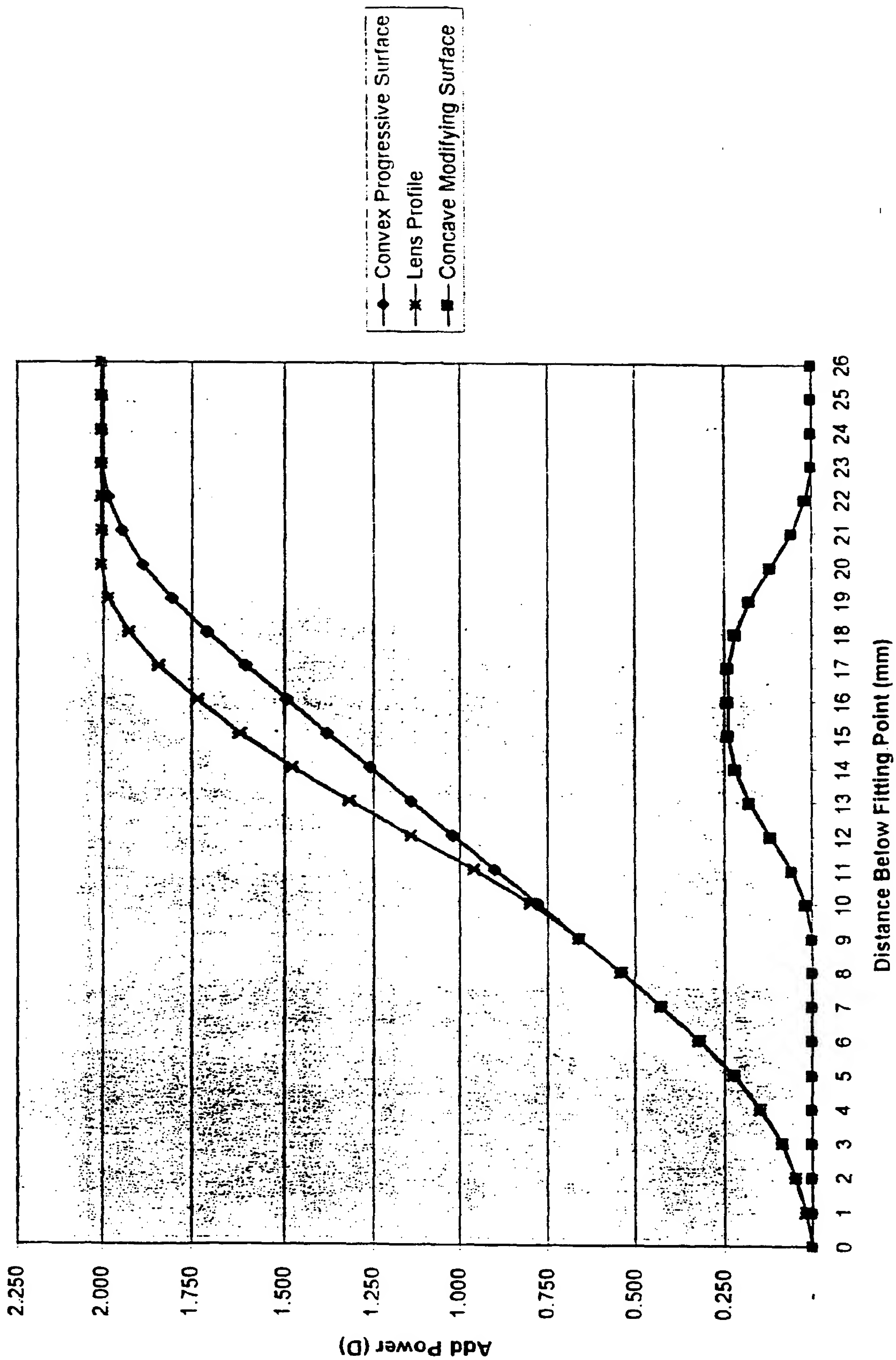


Fig. 6: Example 6 Channel Profiles

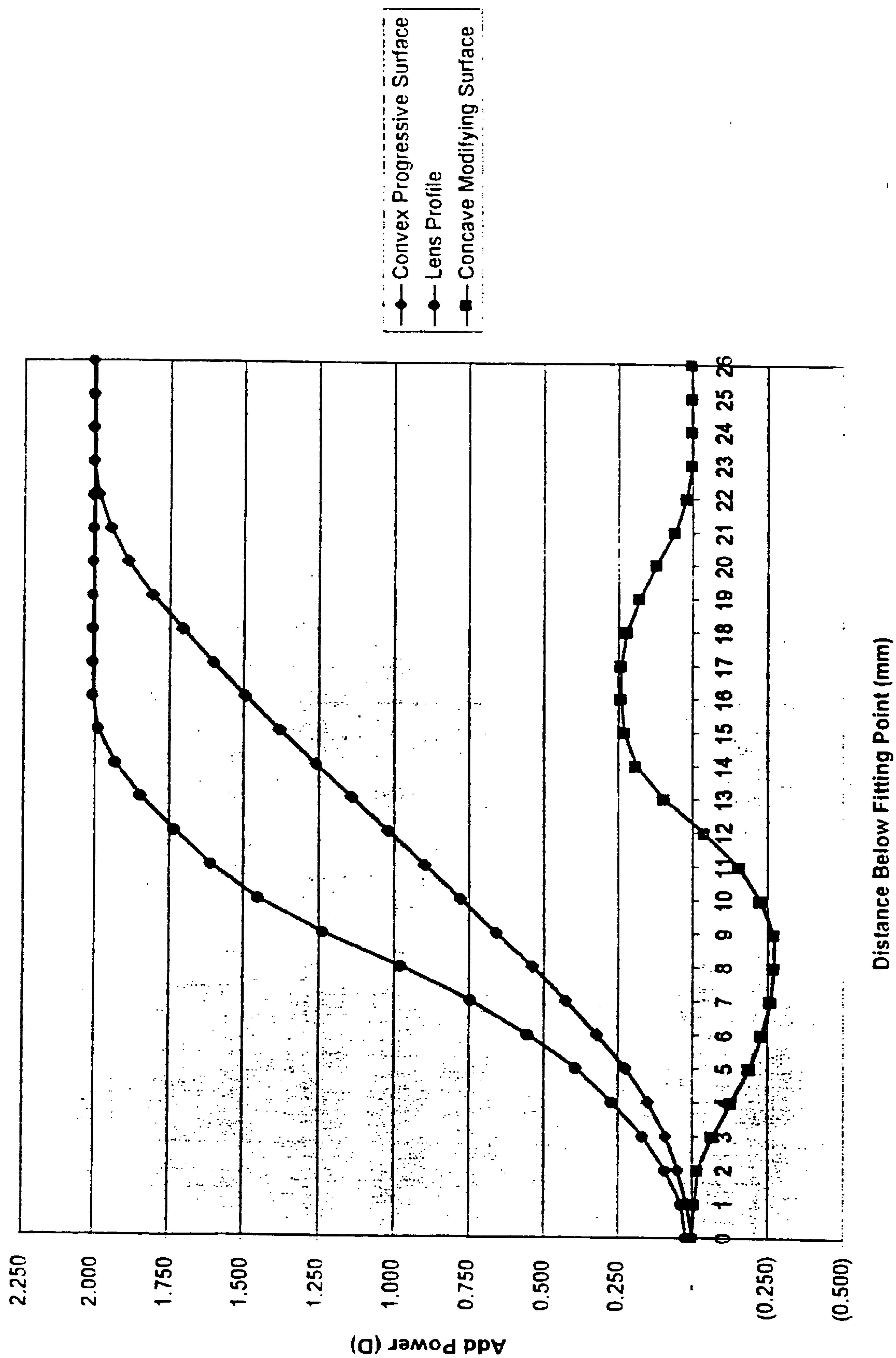


Fig:7 Channel Profiles

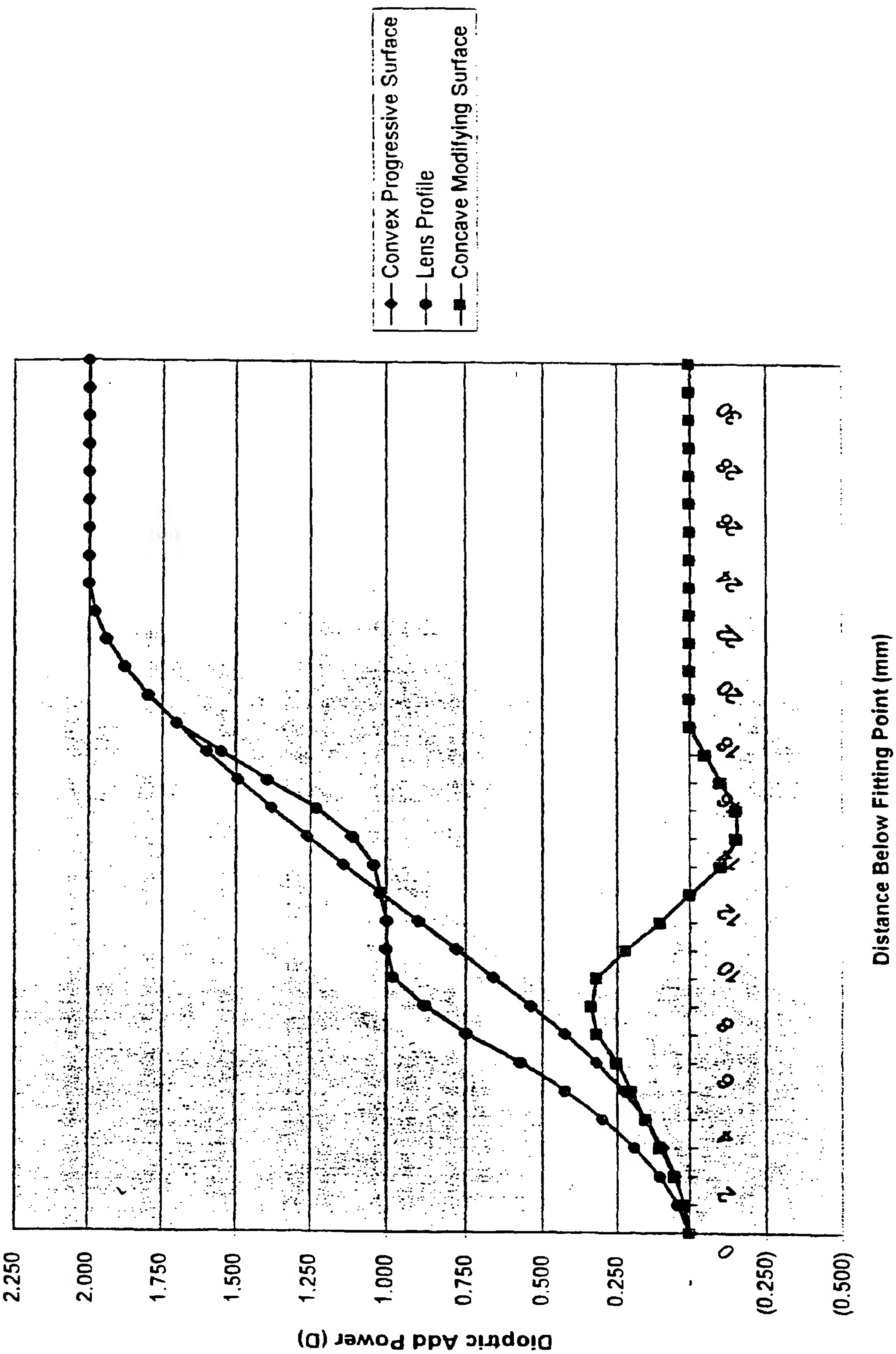


Fig 8: Power Profiles

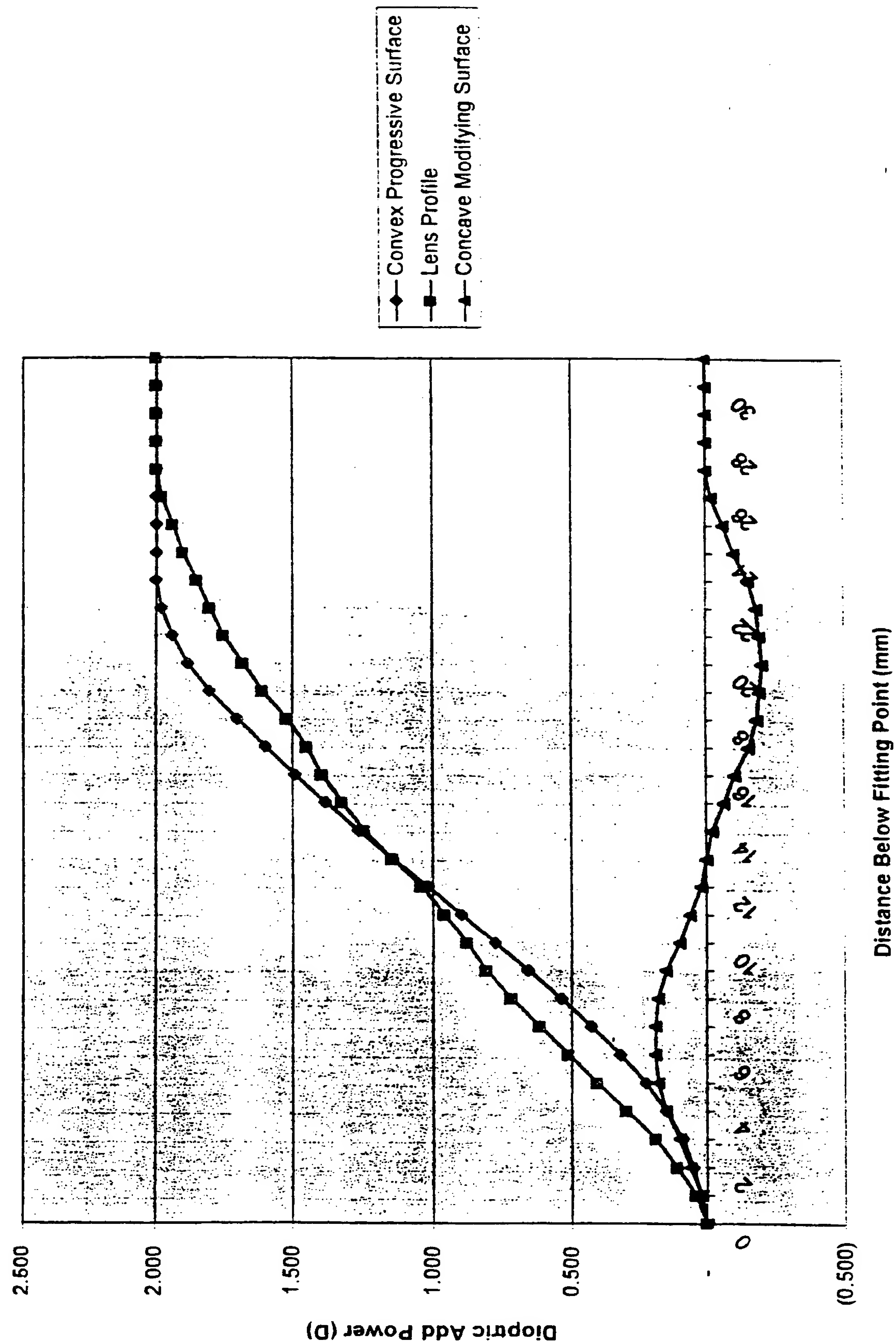
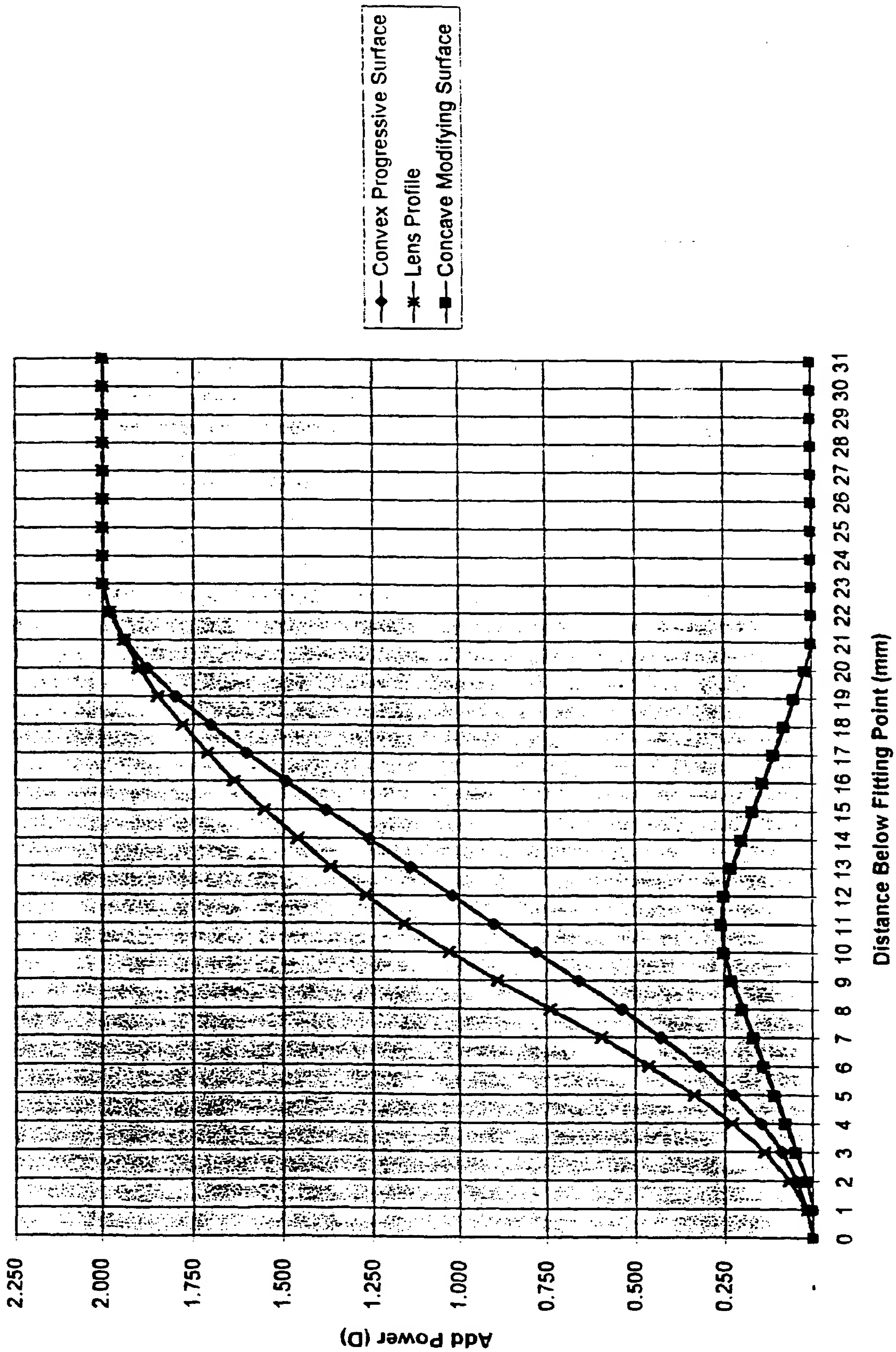


Fig 9: Channel Profiles



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(71) Applicant: JOHNSON & JOHNSON VISION CARE, INC. [US/US]; 7500 Centurion Parkway, Suite 100, Jacksonville, FL 32256 (US).

(72) Inventor: MENEZES, Edgar, V.; 6558 Hidden Woods Drive, Roanoke, VA 24018 (US).

(74) Agent: GIANNESCHI, Lois, A.; Johnson & Johnson, One Johnson & Johnson Plaza, New Brunswick, NJ 08933 (US).

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(57) Abstract: The present invention provides multifocal ophthalmic lenses. In particular, the invention provides lenses in which channel power progression modification is achieved without a significant increase in unwanted astigmatism.

# INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
G02C7/06

According to International Patent Classification (IPC) or to both national classification and IPC[7]

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | WO 99/18471 A1 (INNOTECH, INC.) 15 April 1999, page 3, line 11 - page 9, line 3, page 14, line 1-5. -- | 1-3, 14-16 |
| A | US 5715032 A (ISENBERG) 03 February 1998, column 1, line 38-57, column 3, line 35 - column 9, line 63. -- | 1-3, 14-16 |
| A | US 5771089 A (BARTH) 23 June 1998, column 3, line 12 - column 7, line 43. -- | 1-3, 14-16 |

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☒ Patent family members are listed in annex.

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| C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT | | |
|---|---|---|
| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| A | US 5137343 A (KELCH et al.) 11 August 1992, column 1, line 50 - column 3, line 36, column 5, line 22 - column 6, line 64. ---- | 1-3, 14-16 |

| ANHANG | ANNEX | ANNEXE |
|---|---|---|
| Zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr. | To the International Search Report to the international Patent Application No. | Au rapport de recherche international relativ à la demande de brevet international n° |

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| In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr. | This annex lists the patent family members relating to the patent documents cited in the above-mentioned search report. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. | La presénte annexe indique les membres de la famille de brevets relatifs aux documents de brevets cités dans le rapport de recherche international visée ci-dessus. Les renseignements fournis sont donnés à titre indicatif et n'engagent pas la responsibilité de l' Office. |

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